

## ARCHES NATIONAL PARK RESEARCH SUMMARY 2009

**1) Study Title:** Phylogeny and Evolutionary History of *Anticlea vaginata* Rydb.  
(Melanthiaceae): A Hanging Garden Endemic

**Permit No.:** ARCH-2009-SCI-0001

**Principal Investigator:** Tina Ayers

**Purpose of Scientific Study:** Sheathed Death Camas, *Anticlea vaginata* Rydb. (Liliales: Melanthiaceae) is a rare hanging garden endemic species. This research will add to the body of knowledge about Colorado Plateau hanging garden endemic plant species, assist with the on going endeavor to resolve the complicated taxonomy of the genus *Anticlea*, and assist agencies in future land management decisions involving this species. Knowledge of genetic diversity within populations will suggest which populations are particularly important to protect, and knowledge of gene flow will indicate what hanging gardens, if any, are interacting as subpopulations and which are completely isolated.

This research will address the following questions:

Is *Anticlea vaginata* a distinct taxon?

What is the most likely geographic and biological origin for *Anticlea vaginata*?

Is there gene flow between isolated populations of *Anticlea vaginata* and between *A. vaginata* and *Anticlea elegans*, or does there appear to be continuing diversification? Which populations of *Anticlea vaginata* exhibit the highest levels of genetic diversity, recommending them for future conservation?

What pollinators are visiting this species and which ones seem to be the most important to its fecundity?

**Findings/Accomplishments for 2009:** Sheathed Death Camas, *Anticlea vaginata* Rydb. (Liliales: Melanthiaceae) is a rare, hanging garden endemic plant species.

*Anticlea vaginata* occurs from Dinosaur National Monument south to Arches NP, Canyonlands NP, Natural Bridges NM, and Glen Canyon NRA. There is also one population in Zion NP, one in Grand Canyon NP, and a few in northeastern Arizona on the Navajo Reservation. Very little research has been conducted on this unique species. In order address *A. vaginata*'s validity as a species, amounts of gene flow between populations, and levels of genetic diversity, a combination of molecular data, physical characteristics, and life history traits are being analyzed. For two populations, one leaf from each of 15 individuals was collected for genetic analysis. Pollinators were collected at the same time as leaf collection, resulting in ten potential pollinators being captured for identification. One entire plant was collected from one population to be a voucher specimen and to be included in the analyses of physical characteristics. Genetic and morphological analyses are in progress. Identifying whether or not *A. vaginata* is a good species, knowing its levels of genetic diversity and gene flow, and understanding its basic life history traits will all assist in its management.

**3) Study Title:** Soil Survey of Arches National Park, Utah

**Permit No.:** ARCH-2009-SCI-0003

**Principal Investigator:** Victor Parslow

**Purpose of Scientific Study:** To provide an updated soil and ecological site inventory for Arches National Park (ARCH), that meets National Cooperative Soil Survey (NCSS) standards and park management and planning needs. The existing soil survey was conducted in the late 1970's and the early 1980's as part of the Grand County, Utah soil survey. This inventory was primarily designed as a tool in managing grazing lands and has been found to be too general to be useful for

managing the park. Information is lacking to model salt movement, mitigate visitor impacts, identify and protect habitat of Threatened and Endangered species, and other park responsibilities. In 2003, representatives of the National Park Service approached the Natural Resources Conservation Service to update the soil survey within Arches and Canyonlands National Parks and Natural Bridges and Hovenweep National Monuments. The plan of work and contract were approved in 2004. This application is seeking permission to carry out the necessary field work to complete the contract.

**Findings/Accomplishments for 2009:** No field activities were conducted during this year; a draft soil survey has been produced.

**5) Study Title:** Delicate Arch Trailhead Restoration Project

**Permit No.:** ARCH-2009-SCI-0005

**Principal Investigator:** Tamsin McCormick

**Purpose of Scientific Study:** The proposed habitat enhancement project is part of a larger effort by our conservation organization toward improving wildlife habitats along critical waterways in the high deserts at the heart of the Colorado Plateau. We hope to increase public awareness about the consequences of recreation impacts and unchecked noxious weed invasions and how members of the public can be a part of the solution, while performing hands-on restoration of a degraded riparian area in Arches National Park. We have targeted the area of the Delicate Arch trailhead, a major international tourist destination, to launch a demonstration project. The project includes rehabilitating areas adjacent to Salt Wash near Wolfe Cabin. Efforts in 2009 focused on revegetation of disturbance sites following relocation of the trailhead toilets in summer, 2009. The scope of work was coordinated with NPS Resource Management staff. Plant collection protocols are included in this permit.

**Findings/Accomplishments for 2009:** Disturbance areas identified for revegetation in 2009 included the old toilet pad, which was covered with sandy soil brought in by the NPS (approximately 200 square meters), and social trailing between the main trail and old toilet site (approximately 300 square meters). These areas were planted with 200 one- to five-gallon live plants collected from private and BLM lands within 50 miles of the Park. Planting took place on October 8-9 and November 4, 6, and 23. All transplants were hand-watered weekly through November 23 during weeks with no precipitation. On planting days, staff engaged several members of the visiting public in discussions about the need for the project and the materials selected for planting. Challenges to success of this revegetation project included disturbance in the site, from large animals and visitors and foraging by rabbits, especially of rabbitbrush, globemallow and to a lesser extent, saltbush. This was a particularly dry Fall, and the plants were relatively lush when installed compared with surrounding vegetation. The main social trail was an old roadway that had previously been revegetated by NPS, although only ephedra and yucca obviously remain from this previous planting. The soil was extremely compacted in this area, especially below about nine inches from the surface. It is likely that this roadway had been driven extensively when wet, compacting the fine-textured soils. This hard layer at depth may be a challenge for many of the grasses that were planted, although holes were dug at least nine inches deep and the soil amended. Approximate numbers, by species, planted in the old toilet pad and the visitor impact areas respectively, are as follows:

Grasses:

*Sporobolus cryptandrus* (30,19)

*Stipa hymenoides* (6,28)

*Aristida purpurea* (0,4)

Forbs:

*Sphaeralcea parvifolia* (10,15)  
*Machaeranthera canescens* (5,5)  
*Grindelia fastigiata* (1,6)

Shrubs:

*Atriplex canescens* (>9, >7; 21 total)  
*Gutierrezia sarothrae* (14,10)  
*Artemisia tridentata* (4, 6)  
*Artemisia filifolia* (4, 6)  
*Chrysothamnus nauseosus* (3, 5)  
*Ephedra viridis* (5, 2)

Other forbs identified for revegetation included *Astragalus* spp. and *Oenothera pallida*, which we hoped to collect in the Park, but which were not available. The grass *Sporobolus airoides* was also identified as a possible grass to split from existing grasses, but we chose not to disturb existing healthy grasses at this point, in view of the soil type. Some additional planting, watering and weeding are planned for spring, 2010.

**6) Study Title:** Carbon and Nitrogen Cycles in Arid Lands: The Role of biological Soil Crusts as Influenced by Soil Surface disturbance, Climate Change and Annual Grass Invasion

**Permit No.:** ARCH-2009-SCI-0009

**Principal Investigator:** Jayne Belnap

**Purpose of Scientific Study:** Models indicate the presence of a large carbon (C) sink at temperate latitudes in the northern hemisphere. Over thirty percent of lands both globally and in the United States consist of semi-arid or arid landscapes. Very little is known about carbon dynamics in these regions. Biological soil crusts, composed primarily of cyanobacteria, algae, lichens and mosses, can completely cover plant interspaces in undisturbed areas, and constitute 70 percent or more of the living ground cover. These soil crusts can be the dominant source of nitrogen (N) for vascular plants. They fix C at a high rate and are critical for soil stability and aggregate formation, which is important in C storage. They also absorb significant amounts of CH<sub>4</sub>. In areas where precipitation is low and soils have low fertility, native plants often rely on intact biological soil crusts to provide increased water and nutrient flow to the broadly scattered vegetation. Thus, there are many ways in which biological soil crusts influence biogeochemical cycles and the structure and productivity of the vascular plant community. Soil surface disturbance, invasive plants, and climate change have the potential to dramatically alter the structure and function of biological soil crusts. The current combination of recreational use and livestock grazing is resulting in unprecedented levels of surface disturbance on many arid lands. In regions that did not have substantial amounts of surface disturbance in the Holocene, biological soil crusts disappear readily when trampled by animals or vehicles. Exotic annual grasses are invading many of these areas. Trampling and invasion results in reduced cover and changes in the species composition of biological soil crusts. This, in turn, leads to changes in processes such as decomposition, N and C fluxes, soil moisture, and nutrient availability to vascular plants. Decreases of only 1 percent of soil organic carbon in the top 10 cm of rangeland soils is equivalent to the total C emissions from all croplands nation-wide. Changes in climate regimes, such as a shift in the summer monsoonal boundaries in the western United States, are expected to influence the composition and physiological functioning of biological soil crusts. Various crust components have different photosynthetic and respiration responses to temperature and moisture. In addition, different crusts have different methane fluxes. Therefore, changes in the timing or amount of temperature and precipitation is expected to alter soil C and N

fluxes through changes in physiological response or crustal composition. This, in turn, can significantly impact vascular plant productivity. This project will establish how alterations in species composition by surface disturbance, invasive grasses, and/or climate change may affect N and C inputs and fluxes, in different soils under different climatic regimes. Because current and expected changes in land use and climate will occur over millions of acres in western rangelands, impacts to soil crusts have the potential for dramatically affecting C cycles, N cycles, and vascular plant productivity over much of the western United States. In addition, semi-arid and arid ecosystems represent over one-third of the Earth's terrestrial surface, and most are covered by biological soil crusts. As human impacts are escalating both regionally and globally in these drier regions, the research questions posed in this proposal have significant implications for global C budgets as well.

**Findings/Accomplishments for 2009:** With this ongoing project, we are continuing to maintain our experimental plots and collect data. As we are looking at long-term effects of soil surface disturbance, we will continue to annually monitor change, and analyze data in the future.

**7) Study Title:** Impacts of Climatic Change and Land Use on the Southwestern U.S.  
**Permit No.:** ARCH-2009-SCI-0007

**Principal Investigator:** Jayne Belnap

**Purpose of Scientific Study:** (1) the causes and timing of changes in alluvial environments (rivers, streams, hillslopes), such as flooding, the cutting and filling of arroyos, and sediment discharge; (2) the role of eolian dust for soil fertility, invasion of exotic species, hydrology, and surface stability in deserts; (3) the interaction of physical and biologic processes critical for ecosystem functions; (4) how climate in the southwest has varied over decades, centuries, and millennia; (5) how future climatic variations will affect the Southwestern land surface (in terms of erosion, sand-dune activity, dust-storm frequency, flooding, landslides,); (6) how past climatic changes and environments affected prehistoric cultures.

**Findings/Accomplishments for 2009:** This is a long-term project, with which we hope to understand climatic variability and its effects on dust projection and soil fertility. Multiple years will be required to capture the full range of variability so that we may better understand the role of extreme events, as well as normal regimes.

**8) Study Title:** Firewood movement across state lines by national park visitors  
**Permit No.:** ARCH-2009-SCI-0008

**Principal Investigator:** Betsy Goodrich

**Purpose of Scientific Study:** The purpose of this study is to quantify the number of campers visiting national parks in four western states (Colorado, Arizona, Utah and Wyoming) who are bringing firewood from out-of-state sources. This survey is one objective of a larger research project to assess the risks of transporting invasive forest pests (insects and pathogens) from state to state in the Rocky Mountain region. The research is also a part of a nationwide education effort to reduce these potential risks on a state to state basis. Surveying park visitors (campers) will help us determine the risk of invasive species importation via firewood and help us direct our education and management actions. This project is in cooperation with the Colorado Department of Agriculture and USDA-APHIS.

**Findings/Accomplishments for 2009:** We quantified the number of campers visiting 30 campgrounds in 13 National Parks and National Recreation Areas in the southern Rocky Mountain region (Arizona, Nevada, Colorado, Utah and Wyoming). A survey was conducted in one campground in Arches NP (Devils Garden), one campground in Black Canyon of the Gunnison (South Rim), two campgrounds in Bryce (North and Sunset), one campground in Capitol Reef (Fruita), one campground

in Glen Canyon NRA (Wahweap), two campgrounds in Grand Canyon NP (Desert View and Mather), six campgrounds in Grand Teton NP (Colter Bay, Flagg Ranch, Gros Ventre, Jenny Lake, Lizard Creek and Signal Mountain), one campground in Great Sand Dunes NP (Pinyon Flats), five campgrounds in Lake Mead NRA (Boulder Beach, Calville Bay, Echo Bay, Las Vegas Bay and Temple Bar), one campground in Mesa Verde NP (Morefield), three campgrounds in Rocky Mountain NP (Aspenglen, Glacier Basin and Moraine Park), four campgrounds in Yellowstone NP (Bridge Bay, Canyon, Grant and Madison) and two campgrounds in Zion NP (South and Watchman).

In Arches NP, 18 campers were surveyed during May, 2009. Visitors were asked if they had firewood, where it was from (state source), where they obtained the firewood (wood source: from a local vendor in the park, nearby retail, cut or collected at home, lumber scraps or other) and if it was a conifer or hardwood species (if known). If the camper was willing to let us inspect the wood, details on the appearance were recorded (bark presence, evidence of previous infestation by insects and fungal contamination). In addition, we distributed educational posters and information to campground hosts and park staff, when available.

Over all national parks, we visited 4,522 campsites and 1,658 of these campsites were surveyed with visitors present. The preliminary results indicate 1,116 campers had firewood and 36% of the wood was coming from out of state. Of the 36% of campers with firewood from out of state, 12% of the campers were from the park state, 48% were from a neighboring state and 40% were from farther away. Based on NPS visitor statistics from 2008, this equates to 330,575 campers potentially bringing firewood from out of state. The results varied by state: 23% of campers in Arizona parks brought firewood from out of state, 8% of campers in Colorado parks, 43% of campers in Nevada parks, 57% of campers in Utah and 24% of campers in Wyoming. Of campers with firewood from all parks, 32% of the firewood was purchased inside the park, while 25% was purchased outside the park and 17% was cut or collected from the camper's home and transported to the campsite. Sixty-seven percent of the firewood was conifer with 7% hardwood. Fifty-three percent was found to have presence of previous insect (beetles and borers) infestation while 39% was found to have presence of previous fungi (stain and decay fungi) infestation. Data collection is completed and we are continuing to analyze data and prepare a refereed manuscript.

**9) Study Title:** The three-dimensional geometry and kinematics of brittle structures within the immediate hanging-wall of large extensional faults:  
Implications for subsurface hydrocarbon migration and entrapment

**Permit No.:** ARCH-2009-SCI-0009

**Principal Investigator:** Stuart Clarke

**Purpose of Scientific Study:** In the past few years, the focus of research in to the effects of faults on hydrocarbon migration has shifted from the study of single faults to encompass the geometrical relationships between spatially limited but kinematically linked faults, and the effects that related structures such as deformation zones at tip points, relay ramps and fault linkages may have on migration. A number of recent studies (e.g.: Rotevan et al., 2007; Johansen et al., 2005; Fossen et al., 2005; Berg & Skar, 2005) have examined the development of damage zones (deformation bands, joints and sub-seismic scale faulting) associated with en-echelon faults, relay ramps and splay faults. This study will examine the structural geometry and detail of a number of sub-seismic-scale, en-echelon fault segments and related structures that are well-exposed within the hanging-wall of a large, seismic-scale, extensional fault within the Cache Valley, Arches National Park, Utah, U.S.A. The study will examine the accommodation of strain within the hanging-

wall to investigate the development of these sub-seismic extensional structures in relation to deformation on the seismic-scale fault. Fully balanced structural models will be developed and their analysis will allow the prediction of sub-seismic-scale brittle structures in the hanging-wall blocks of seismic-scale faults from the observed displacement parameters on these larger structures. These smaller-scale structures, and their relationships to larger scale structures are of particular relevance in subsurface hydrocarbon reservoirs because of their effects on hydrocarbon migration: the smaller scale structures are below the resolution resolvable of seismic survey and therefore cannot be imaged directly in such settings.

**Findings/Accomplishments for 2009:** The fieldwork aspect of this research project was completed in September 2009. Statistical analysis of the results and construction of a preliminary three-dimensional model is on-going and expected to be completed in the 1st quarter of 2010.

**10) Study Title:** Three-Dimensional Characterisation of Faults and Their Influence on Fluid Migration.

**Permit No.:** ARCH-2009-SCI-0010

**Principal Investigator:** Stuart Clarke

**Purpose of Scientific Study:** Research to study the effects of faults on the migration within, and subsequent extraction of hydrocarbons from, sedimentary basins on basin- field- and trap-scale.

**Findings/Accomplishments for 2009:** The fieldwork aspect of this research project was completed in September 2009. Construction of a preliminary three-dimensional model for field data is on-going and expected to be completed in the 1st quarter of 2010.

**11) Study Title:** Annual Forest Land Inventory of Utah

**Permit No.:** ARCH-2009-SCI-0011

**Principal Investigator:** Renee O'Brien

**Purpose of Scientific Study:** The Interior West Forest Inventory and Analysis program is responsible for statewide inventories in eight states. The purpose of this ongoing inventory is to gather information on condition and trends of forest resources to assess plant diversity; fuels and potential fire hazards; condition of wildlife habitats; mortality and risk associated with fire, insects, or disease; and biomass, carbon storage, forest health and other general characteristics of forest ecosystems. Under the annualized inventory system, each field plot is visited one every 10 years, with approximately 10 percent of the total plots visited each year within a state. The FIA program produces a fiveyear report for each State.

**Findings/Accomplishments for 2009:** As part of the Annual Forest Land Inventory of Utah, field crews visited two plots at Arches National Park during the 2009 field season. One of these plots met the Inventory's definition of forest land, and field crews performed a non-consumptive vegetation inventory on this plot. The results of this ongoing inventory are periodically updated and made available at [www.fs.fed.us/rm/ogden/publications/](http://www.fs.fed.us/rm/ogden/publications/). The fiveyear report for the Utah inventory will be released in Spring 2010. Site-specific summaries of field data, in PDF form, will be sent to the designated NPS contact person.

**13) Study Title:** Determinants of geographic distribution in western North American monkeyflowers

**Permit No.:** ARCH-2009-SCI-0013

**Principal Investigator:** Seema Sheth

**Purpose of Scientific Study:** The goal of this research is to evaluate the roles of evolutionary and historical processes in shaping the geographic distributions of

species. To do so, we are focusing on species of monkeyflowers that occur in western North America. Specifically, we are addressing two main objectives: 1) Limits to niche evolution: Evaluate whether adaptive genetic variation and response to selection are lower in marginal populations than in central populations within species, and lower in species with narrow niches than in species with broad niches; 2) History: Assess the relative roles of the vicariance and long-distance dispersal hypotheses in explaining geographic patterns of speciation. To determine whether reduced evolutionary potential at species' range margins limits species' responses to natural selection, our aim is to collect seed from *Mimulus eastwoodiae* populations and conduct artificial experiments to compare quantitative genetic variation between central and marginal populations within its range. To determine whether rare species are products of historical events, our goal is to collect leaf tissue from populations across the geographic range of *Mimulus eastwoodiae* to infer historical demography from patterns of genetic variation.

**Findings/Accomplishments for 2009:** We visited one population of *Mimulus eastwoodiae* in an alcove adjacent to the Delicate Arch Trail. We collected one fruit from each of two individuals in the population, and leaf tissue samples from each of 17 individuals in the population. We planted one fruit in the Colorado State University Greenhouse, but the fruit capsule appeared empty and there was no germination. We have not yet extracted DNA from leaf tissue samples. We may do additional collecting of *Mimulus eastwoodiae* fruits in Arches National Park in summers 2010 and/or 2011.